Ohio Agricultural Experiment Station.

BULLETIN 64.

WOOSTER, OHIO, DECEMBER, 1895

THE SMUT OF OATS

AND ITS PREVENTION.

The Bulletins of this Station are sent free to all residents of the State who request them. Persons who may receive duplicate copies, or who do not care to receive any, are requested to notify the Station. All correspondence should be addressed to

EXPERIMENT STATION, Wooster, Ohio.

COLUMBUS, OHIO:
THE WESTBOTE CO., STATE PRINTERS.
1896.

ORGANIZATION OF THE

OHIO AGRICULTURAL EXPERIMENT STATION.

BOARD OF CONTROL.

SETH H. ELLIS	Springboro
R. H. WARDER	North Bend
J. T. ROBINSON	Rockaway
THE GOVERNOR OF THE STATE THE DIRECTOR OF THE STATION	*Ex-officio*

OFFICERS OF THE BOARD.

SETH H. ELLIS	President
R. H. WARDER	Secretary
PERCY A. HINMAN	Treasurer

STATION STAFF.

CHARLES E. THORNE	Wooster	Director
WILLIAM J. GREEN	"	Horticulturist and Vice-Director
J. FREMONT HICKMAN, M. A. S	"	Agriculturist
FRANCIS M. WEBSTER, M. Sc.	"	Entomologist
AUGUSTINE D. SELBY, B. Sc.	"	Botanist and Chemist
PERCY A. HINMAN	"	Bursar
EDWIN C. GREEN	"	Assistant Horticulturist
WILLIAM HOLMES	"	Foreman of Farm
CHARLES A. PATTON	"	Ass't Foreman and Meteorologist
W. A. PORTER	"	Florist
H. O. MCFADDEN	"	Foreman of Gardens
WILLIS G. HARRY	"	Dairyman
ANNA B. AYRES	"	Mailing Clerk
S. J. BLAKE	"	Mechanic
J. E. BARCLAY	Neapolis	Supt. Northwestern Sub-Station
EDWARD MOHN	Strongsville	Supt. Northeastern Sub-Station

The Bulletins of this Station are issued at irregular intervals. They are paged consecutively, and an index is included with the Annual Report, which constitutes the final number of each yearly volume.

BULLETIN

OF THE

Ohio Agricultural Experiment Station.

NUMBER 64. December, 1895.

THE SMUT OF OATS AND ITS PREVENTION.

BY AUGUSTINE D. SELBY, B. SC., BOTANIST.

The blackened panicles of oats, so conspicuous at blossoming time, have been observed by almost every person who has seen a field or plot of this grain. That this condition, known as smut, is a disease caused by the parasitic growth of a microscopic plant, the oat-smut fungus, is also generally known. It is only quite recently that successful and cheap prevention has been devised, a result of that spirit of experimental investigation, characteristic of our century. The smut of oats has been the subject of special investigation by Jensen,[1] by Kellerman and Swingle,[2] by Arthur[3] and by others.

The oats at this Station, especially in the variety plots, having become seriously affected with smut, and with apparent rapid increase in amount from year to year[4], experiments in treatment of seed were undertaken; later, with the maturity of the oats crop for the season, efforts were made to determine the amount of smut in different parts of the State. The results of these investigations seem worthy of publication; this conclusion has been reached in view of the considerable losses occasioned by smut in oats and the comparative tardiness with which methods of prevention have as yet found general application in this State. It appears at present, that seed treatment is a neglected source of profit in oats production, and the general realization of this profit is the problem here offered.

---

[1] See Journal Royal Agricultural Society of England, 1888, Vol XXIV S. S., Part II, pp. 397—415.

[2] See Bulletins and Reports of Kansas Experiment Station: 1889, B. 8, 2d. An. Rpt.; 1890, B. 15; 1891, B. 22.

[3] See Report of Botanist New York Experiment Station, 1884, and Bulletins Indiana Experiment Station: 1889, B. 28; 1891, B. 35.

[4] Hickman, J. Fremont, Bulletin 57 (1895) p. 115.

HISTORICAL.

The oat plant, *Avena sativa*, has been cultivated almost or quite as long as the wheat plant; the references to smut in oats do not cover so long a period, apparently, as do those in regard to smut in wheat.[5] The earliest distinct mention, of which we possess information, is that of Tragus in 1552. In 1591 Lobelius[6] gave a figure of oat smut under the name of *Ustilago Avenæ*. The fungus was long known, later, as *Ustilago segetum* (Bulliard) Dittmar, und *Ustilago Carbo* Tulasne; for this period the loose smuts of wheat, barley and oats were regarded as identical. In 1888[7] Jensen named the loose smut of oats *Ustilago segetum* var *Avenæ*, and in 1889[8] *Ustilago Avenæ*, recognizing it as a separate species. This view is meeting with quite general acceptance. In accordance with botanical usage, we write *Ustilago Avenæ* (Persoon) Jensen, since pre-Linnæan names are not taken up. The botanical history of the smut fungus is thus necessarily interwoven with the occurrence of the disease it causes in this cereal.

The introduction of oats into the American colonies took place very early. It was sown in Newfoundland in 1522 and in the Colony of Massachusetts Bay in 1629[9]; good crops of oats are reported in Lynn, in 1633.[9] But while this early oats growing was probably attended by the occurrence of smut, we search almost in vain for early references to it. In the index to reports of United States Department of Agriculture, 1837 to 1876, the earliest mentioned article on oat smut is in 1873; references to wheat smut (stinking smut of wheat) are frequent in the index named, and in the files of early agricultural journals. In all these sources consulted there is the same dearth of information concerning oat smut. In this respect, however, we are no worse off than England. The earliest indexed reference to oat smut in the Journal of the Royal Agricultural Society, is the article by Jensen, before referred to. The edition of Ellis[10] examined makes no mention of smut in oats. It would be strange were there no earlier references to this smut in America, but the one "seen" bears date of 1820,[11] and refers particularly to rain-washing in the field as a preventive. Eight subsequent and successive volumes of the American Farmer make no mention of oat smut. The Cultivator[12] from 1846 to

---

[5] Kellerman and Swingle, 2d An. Rpt. Kansas Exp. Sta., 1889, p. 215.
[6] Kellerman and Swingle, loc. cit., p. 215.
[7] Jensen, J. L., loc. cit., p. 407.
[8] Jensen, J. L., Le Charbon des Cereales, p. 4 (K. & S.)
[9] Report U. S. Com'r Patents (Agriculture) 1853, p. 158.
[10] Ellis's Husbandry, London, 1772, kindly loaned by Prof. F. M. Webster.
[11] American Farmer (Balto.) Vol. II, No. 27 [Sept. 29], 1820, p 215.
[12] Cultivator (Albany, N. Y.), Vol. IV Third Series, 1856, p. 139 and p. 158.

1865, appears to have two references to smut in oats. In the History of Vegetable Substances,[13] Vol II, the author, while treating of both wheat and oats with more or less of detail, and mentioning the commoner diseases of wheat, makes no reference to smut in oats. Fox[14] in his text book of Agriculture, makes this mention: "Smut (*black heads—Uredo Segetum*) appears to be the only fungus to which it (oats) is generally subject, and this, rarely to any extent". Instances might be multiplied to show how rarely attention has been called in the past to the disease, which appears to have been taken as a matter of course.

This old view bears emphasis in order to point out its fallacy; the tendency still seems to be in the same matter-of-course way. That the trouble has a specific cause and specific conditions of development, requires frequent repetition. It is apparently well proven that, without the presence of smut spores in the vicinity of the growing grain which is to furnish seed oats, or to a less extent, an adhesion of spores through threshing, no smutted panicles will occur. In the case under discussion only those spores which are within the husk of the seed oat seem capable of causing smut in the oat plant[15]. This is shown by the artificial smutting of seed just before the sowing. A very slight difference in the amount of smut produced, between plants from seeds smutted by dusting spores upon them and those from seed not so treated, has been observed by many experimenters. The reference just given to Jensen's work covers this point also.

The explanation appears to rest on the fact that the spores are disseminated at blossoming time. And since the spores adhering to the exterior of the kernel are, for the most part, ineffective in producing smut, it must be those spores which find entrance within the husk that cause the infection. "As the kernels of oats and barley are tightly embraced by the husk, except when the husk opens to allow the stamens to protrude, it follows that this period is the most favorable for the infection of the grain."[16] The spores are apparently not effective in producing smut the season they may find entrance. In our current year's work, four small plots were experimented upon to secure data upon this point. On two plots, spores were carefully dusted, at blossoming time, the operation being repeated to infect, if possible, all panicles; on the other two, no dusting was done. Practically no difference was found in the amount of smutted heads; the results of counts will be given later. The applica-

[13] History of Vegetable Substances Used in the Arts, etc., and for the Food of Man, Vol. II, Boston, 1833.

[14] Fox, Charles, Am. Text Book of Agric., Detroit, 1854, p. 105.

[15] Jensen, J. L., Propagation and Prevention of Smut in Oats and Barley, Jour. Roy Ag. Soc. S. S. II, 1888, pp. 401—403.

[16] Jensen, loc. cit., p. 403.

tion of the matter, just stated, lies in seed selection or seed treatment after methods given in this bulletin.

It is to the labors of Jensen, Kellerman and Swingle, Arthur and others since them, that we owe the marked recent progress in smut prevention in America, and the advance of experimental knowledge concerning smut infection.

DAMAGE CAUSED BY SMUT.

The effect of smut upon the oat plant, in this case the host, is generally confined to the grain and grain bearing parts, particularly the glumes. The smut has been found upon the leaves of oats grown in greenhouse from seed obtained at this Station,[17] and perhaps others have so found it. But the real injury with which we have to deal is that of grain destruction. The smut of oats, like other loose smuts, commonly converts the grain and its surrounding glumes or chaff into a black, powdery mass. See Figs. 2 and 3, Plate I. The dark, dirty aspect of the diseased panicles has given rise to the name "smut". When grains and glumes are both affected it is easy to distinguish the smutted heads upon their emergence; the whole is black and sooty with entire destruction of the grain. This may be regarded as the more common condition, both as to appearance and as to loss of grain in smutted plants. But the smut often destroys the grain without converting the empty glumes into dust. In some varieties this is notably the case. In Black Prolific the feature was noticed, also in Race Horse, and to a greater or less extent in all varieties. An extreme form of this sort, is that in which the flowering glume remains intact while the kernel within is smutted, the form called "hidden smut" by Kellerman and Swingle.[18] Where this hidden smut occurs, cutting through the spikelet will disclose it. One who has to do with this form, will soon note external characters which generally suffice to distinguish it without recourse to cutting open the glumes. Among these entirely smutted panicles with empty glumes intact, occur those in which the lower part of the head is smutted while the upper spikelets bear sound grains. See Fig. 1, Plate I. An extreme example was found in Race Horse, where the lower kernel of a spikelet was sound and the upper one destroyed by smut. Brefeld[19] appears to have offered a sufficient explanation of this partial smutting of heads, by the upper portion's outgrowing the fungus mycelium and thus escaping infection.

---

[17] Prof. L. R. Jones, Burlington, Vt., in letter of Dec. 7, 1895.

[18] Bulletin Kas. Exp. Sta., No. 20, 1890, p 100.

[19] Brefeld, Nachrichten aus dem Klub der Landwirthe zu Berlin No. 221, p. 1592; also Journal Mycology, Vol. VI., p. 154.

The smutted plants commonly have a normal appearance until just before blossoming. As the smutted panicles appear, the entirely dusty ones are very evident. At no later time is the smut in the plot of grain so conspicuous as near the close of the blossoming period. When the grain has ripened, the dusty spikelets will have shed their infecting spores; the straw stands stiff, erect, and somewhat greener than healthy straw. It is worthy of note that nearly all stalks of a smutted hill are smutted; the large number of stools in smutted areas suggests that the disease may produce abortive stooling, where the grain is badly affected. The total heads found in equal areas, as shown in the table (p. 136) offers like general evidence.

The oats grower is more directly interested perhaps in the destruction wrought by the smut.

AMOUNT OF SMUT AND LOSS OF CROP IN OHIO.

Since practically all smutted heads are lost to grain bearing, the per cent. which represents the actual proportion of smutted to the total number of stalks, will also give the part of crop lost by the disease. Perhaps this intangible part lost, stands somewhat in the background and is unappreciated, yet the proposition just stated with respect to amount of loss in crop, admits of easy mathematical demonstration.

From a bulletin by the Agriculturist of this Station[20], we find that the varieties of oats on the Station grounds, in which determinations were made, had the following per cent. of smut in 1894:

Black Prolific, 34 per cent.; American Banner, 13.9 per cent.; Race Horse, 19.1 per cent; Lincoln, 29.0 per cent.; Seizure and White Wonder, each, less than 1 per cent.; Welcome, 1.7 per cent.; Wideawake, 2.6 per cent.; Mammoth Russian (Cluster), 5.9 per cent.; Great Northern, 20.2 per cent.; White Superior Scotch, 21.7 per cent.; AN AVERAGE OF 14.53 PER CENT.

AMOUNT OF SMUT IN 1895.

A number of counts were taken in the oats at the Station in 1895, to determine the amount of smut in untreated areas. As will be seen these results are very high. The smut counts in 1895 are given in Table I:

[20] Bulletin No. 57, pp. 114-115.

TABLE I.—SMUT COUNTS IN OATS AT OHIO AGRICULTURAL EXPERIMENT STATION, 1895.

Variety, location and other conditions.	Total stalks counted.	No. with smutted panicles.	Per cent. smutted.
¿Australian Giant, variety plots	1,726	197	11.41
American Banner, smut plots	2,633	910	34.56
¿Badger Queen, variety plots	1,591	107	6.73
¿Barley Oats, variety plots	1,512	142	9.39
Black Norway, smut plots	1,995	902	45.21
Black Prolific, smut plots	2,557	794	31.05
Black Russian, variety plots	1,901	231	12.31
Calgary Gray, variety plots	2,084	257	12.30
¿Centennial, variety plots	1,299	98	7.54
¿Clydesdale, variety plots	1,671	61	3.66
¿Colonel, variety plots	1,547	182	11.76
Early Archangel, variety plots	1,718	588	34.23
Everett's Negro Black, variety plots	1,747	432	24.73
¿Hargett's White, variety plots	879	42	4.78
¿Henderson's Clydesdale, variety plots	1,241	71	5.72
Lincoln, variety plots	1,942	627	32.29
Lincoln, smut plots	3,033	1,784	58.82
Mammoth Russian (Mam. Cluster), smut plots	2,345	457	19.49
Monarch, variety plots	2,102	198	9.42
New Red Rust Proof, smut plots	1,434	264	18.41
Race Horse, smut plots	4,051	1,627	40.16
¿Race Horse, variety plots	1,449	498	34.37
Royal Doncaster, variety plots	1,459	76	5.21
Seizure, smut plots	3,774	332	8.80
Welcome, variety plots	1,473	112	7.60
¿Welcome, variety plots	1,862	82	4.40
¿White Belgian, variety plots	1,169	135	11.55
¿White Bonanza, variety plots	1,223	68	5.56
¿White Wonder, variety plots	1,039	59	5.68
Wideawake, variety plots	1,304	221	16.94
*Wideawake, Fertil. plots: no Fertilizer	1,193	239	11.65
*Wideawake, Fertil.: Dis. Bone Bl'k, Mur. Potash	1,344	194	14.43
*Wideawake, Fertil.: Dis. Bone Bl'k, Nit. Sod., Mur. Pot.	1,634	199	12.12
*Wideawake, Fertil. plots: no Fertilizer	1,126	203	18 02
†Wideawake, Fertil. plots: no Fertilizer	1,125	209	18.58
†Wideawake, Fertil.: Dis. B. Bl'k, Dried Blood, Mur. Pot.	492	105	21.30
†Wideawake, Fertil.: Dis B. Bl'k., Sulp. Am., Mur. Pot...	1,375	214	15.56
†Wideawake, Fertil. plots: no Fertilizer	1,391	237	17.04
‡Wideawake, Continuous Oats plots: Barnyard Man	1,161	219	18.86
‡Wideawake, Cont. Oats plots: no Fertilizer	1,062	261	24.57
‡Wideawake, Cont. Oats plots: Dis'd Bone Bl'k, Nitrate Soda, Mur. Potash	1,061	190	17.90
Totals and average per cent	68,724	13,824	20.12

¿ Counts made by the Agricultural Department.

*, † ‡ and are series of adjacent plots.

For a portion of the counts above given, this department is under obligations to the Agricultural Department of this Station. In nearly all cases, except smut plots, the counts were made by measuring off 10 feet on each of eight drill rows and counting total stalks and smutted stalks in each row.

It is evident from the above results—an average of 20.12 per cent. smut, compared with those which follow less than 3 per cent.—that the oats at the Station have become worse affected with smut than the average in the State. This may, it seems, be properly attributed to growing varieties, including many susceptible ones, continuously from the same seed; a procedure rendered necessary by the conditions of variety experiments. Obviously the remedy is the treatment of all seed, which, I am informed, is to be the plan for 1896.

In addition to the results at the Station, determinations of the amount of smut in their several neighborhoods, were made by the following gentlemen to whom my obligations are gratefully acknowledged: Mr. John Begg, Columbus Grove, Putnam county; Mr. L. L. Bogue, East Orwell, Ashtabula county; Mr. Nelson Cox, Ensee, Lawrence county; Mr. F. M. Selby, Bartlett, Washington county; Mr. W. H. Todd, Vermillion, Erie county; and Mr. G. W. Breinzer, Canaan, Wayne county. The results are in part estimates or based upon limited counts; the latter are given where they throw light upon the percentages. These counts are given in Table II:

TABLE II.—Smut Counts in Different Parts of Ohio, 1895.

Variety and other conditions.	Total stalks counted.	Number smutted.	Per cent. of smut.
Reported by Mr Begg (Allen County):			
White oats	45	1	2.2
White oats, sown last of March			2.0
Scottish Chief, sown first of April			0.5
White oats, sown on wheat stubble April 13	40	3 to 7	12.5
Variety not known, sown last of March, on clover sod			0.5
Golden, sown April 5, on wheat ground			1.5 to 2.0
Reported by Mr. Bogue (Ashtabula County):			
White Russian, unphosphated sown April 25	454	46	10.13
" " phosphated, April 25	490	31	6.33
" " phosphated, corn stubble April 25	445	16	3.60
Nelson Cox, Lawrence County, says:			
"Not a single head of smut seen in oats this year."			
Reported by Mr. Selby (Athens County):			
Seizure, sown April 12	649	21	3.24
Golden Giant, sown April 10	627	7	1.12
Banner, sown April 12	621	11	1.77
Japan, sown April 4	514	5	0.97
White Swiss, sown April 4	527	3	0.57
Mr Breinzer reports			0.15
Mr. Todd (Erie County) reports:			
Race Horse and Badger Queen mixed	2,000	40	2.00
Totals	6,412	186	2.90

The counts at the Station show 20 per cent. of smutted stalks, therefore a loss of 20 per cent. in the crop, or, to put it another way, the crop harvested is 80 per cent. of what would have been the result under other like conditions, if the seed had been so treated as to prevent all smut. As will be seen from the results of treatment, this season, the treatment will do more than prevent the loss of smut; it will increase the yield beyond replacing this smut loss. Other localities from which estimates or counts were obtained, give an average of 3 per cent. of smutted heads, and a loss of like amount. Which result, if either, represents an average for the State, it would not be easy to determine, unless more extended counts were made. Estimates may mislead, since, upon actual count, the per cent. of smut is nearly always found to be higher than estimated. The observations made the present season, lead me to a higher estimate

of the per cent. of smut than given by the various reports outside the Station. I am convinced that 6 per cent. represents the amount for the whole State very closely, and is more likely to fall below than rise above the general loss.

The average oat crop in Ohio for 1890 to 1894 is 25,168,000 bushels, with an average value of 30 cents per bushel, giving a total of $7,550,000 annually. The estimated yield for 1895,[21] is in round numbers, 32,000,000 bushels, having a value of $8,000,000. Six per cent. on this amount gives a loss of $480,000. A sum certainly worthy of recovery.

Quoting from a recent article by W. T. Swingle,[22] who has given much study to grain smuts: "It is undoubtedly a conservative estimate to place the direct loss from oat smut at 8 per cent. of the crop. Even at this estimate the loss in the United States is over $18,000,000 annually, averaging $18,504,140 for the years 1890 to 1893."

BOTANICAL CHARACTERS OF THE FUNGUS AND MANNER OF INFECTION.

We have already given the botanical name of the oat smut fungus, *Ustilago Avenæ* (Pers) Jens.; the variety of hidden smut has been noted to have smooth spores,[23] and was named *Ustilago Avenæ levis* (Pers) Kell. & Swing.[24]

This fungus and its variety belong to the order USTILAGINEÆ, THE SMUTS, which includes the smuts of barley, wheat, millet, corn and others. These diseases are all of them destructive, and particularly of the seeds and seed producing parts of the infected plants. Other parts are affected in some cases. In common with all smut fungi, *Ustilago Avenæ* is a parasitic plant, whose threads, *mycelium*, grow in the tissue of the host plant, sending specialized branches into the cells. Those branches of the mycelium which bear or produce spores at their tips, tend to become gelatinous and to disappear. This renders it difficult to find the branches after the

---

[21] From estimates of the State Board of Agriculture October 1, 1895, kindly supplied by Secretary Miller.

[22] Causes and Prevention of Grain Smuts, Year Book, U. S. Dep. Agric., 1894, p. 413.

[23] Kellerman and Swingle, Bul. 15, Kans. Exp. Sta., 1891, p. 101. See also Swingle, loc. cit., p. 412 note.

[24] Kellerman and Swingle, 2d An. Rpt. Kansas Exp. Sta., 1889, p. 259.

NOTE. The earliest distinct description of hidden smut in oats that has come under the writer's notice is in The Cultivator (Albany, N. Y.,), Vol. IV, 3 S. 1856, p. 139:

"..... So general was this disease spread over this portion of country, and so unexpectedly, too, was it to our farmers, that no little surprise has been manifested. The crop grew luxuriantly, and promised to be as fine as we ever had (and it was heavy strawed), but after earing, the destructive ravages of the disease above mentioned made itself apparent. In many fields one-fourth, and in some one-third of the ears were entirely worthless. *It is different from what is called "blasted oats," the grain having the proper form but filled with a black dusty substance,* which is offensive to smell, and renders it unfit for food, especially for the horse, when cut with the straw cutter;....."

(Italics mine.) "A PLOWMAN, *Canton, Ind.*"

spores approach maturity. The spores are produced in large numbers, constituting the dark masses which we find in place of the kernels and glumes, or destroying the kernels enclosed in apparently healthy glumes. For purposes of ordinary examination, the spores suffice. They are the bodies which reproduce the fungus, serving the same purpose as seeds in higher plants. Truly among the smuts we can say, 'without the spores no smut in grain.' The spores are minute, dark, mostly oval bodies, measuring 6 to 9x5 to 7 micromillimeters, approximately 1-3200 of an inch in longer diameter. In the ordinary form these spores are minutely spiny or warty, but smooth in the variety called *levis*.

Placed in a suitable nutrient solution, or less satisfactorily in distilled water, the spores will germinate in a thoroughly characteristic manner. This character is described by the works on fungi. It is to the spores which have found their way into the groove or opening of the husk that infection is attributed by Jensen.[25] Lodged there or adhering to the moistened seeds,[26] the spores are quickened by the same conditions that induce the germination of the seed oats. The, usually single, germ tube or thread, sent out by the germinating spore, finds entrance into the seedling oat plant only through the first sheath leaf, while the plant is very young and delicate. If infection does not take place at this early stage it cannot occur.[27] Some discussion has arisen as to the effect of barnyard manure upon propagation of oat smut. The results of experiments made upon this subject seem to indicate that the infection occurs by means of the spores adhering to the seed. The most conspicuous evidence adduced is that brief immersion of the seed in hot water, or longer in other media, is enough to prevent the smut. This seed immersion, manifestly, can have effect only on those spores adhering to the seeds, and none whatever upon any that might be in the manure. But the mistake of applying this argument to corn smut, upon which seed treatment has no effect, as shown by experiments by this department in 1895, should be avoided. Brefeld[28] and von Tubeuf,[29] have both shown that the effect of barnyard manure is to propagate corn smut. We are learning the necessity of distinguishing these heretofore confused life histories of the smuts of our common cereals.

But to return to the smut fungus which has penetrated the young tissues of a seedling oat plant: It continues to grow within the developing plant, the mycelial threads, branching, send sucking or feeding

---

[25] Loc. cit., p. 404.

[26] In this connection, consult Kellerman and Swingle, loc. cit., p. 236.

[27] Brefeld, loc. cit., p. 1590. Also Jour. Myc., Vol. VI, pp. 67–71.

[28] Brefeld, loc. cit., p. 1591. The same influence is claimed for oats and barley.

[29] von Tubeuf, Pflanzenkrankheiten, 1895, p. 295.

branches, *haustoria*, into the cells of the host. Other branches of the mycelium reach the inflorescence, and there, at the proper time, produce the spores of the fungus. Unless the fungus reaches the growing points, it fails to produce smut in the plant.

Brefeld[30] has, moreover, shown that while the germ tubes of any smut may penetrate other seedlings than those of its host, this penetration does not produce the disease in the foreign host. A point of value comes here, with respect to the presence of spores of other smuts among the seeds of any grain. These smut spores may grow but do not cause disease, except upon the host peculiar to them. Oat smut will not give rise to either sort of wheat smut, nor the reverse; nor can corn smut give rise to any of those mentioned except corn smut. While the fungus parasite has from a very early stage been growing within the affected oat plant, spore production is to us, the first manifestation, in gross. That the effect appears as if unannounced, led to the old view of some physical defect in development due to inorganic agencies working upon the grain plants. The evidence before adduced and that which follows in results of treatment, seem more than enough to prove the present doctrine; this leaves out of consideration the direct evidence, always the most valuable, furnished by microscopic examination of the fungus in the host plant.

LIFE HISTORY OF OAT SMUT FUNGUS.

The beginning of the life cycle, as of the smut infection of the oat, is in the spore or spores previously produced and having lodgment upon or within the oat husk. The spores so adhering may be distributed by the wind, at or subsequent to blossoming, or become attached in threshing. It is believed that the former method is most usual with oat smut. With the oat husk intact, those spores which are within the husk or the opening of the husk, are, by their germination, most capable of causing infection. The infection results from the growth of the spore by sending out a germ tube which enters the young seedling exclusively while the seedling is very small, and, moreover, only by penetration of the germ tube through the first sheath leaf, and thus into the plant tissues. When the leaves of the seedling have protruded a short distance beyond the sheath, the germ tubes can no longer penetrate and infection cannot occur. The germ tubes which find entrance into the oat plant by penetration as above, continue to grow, developing a mycelium within the growing or dormant plant, branching and feeding upon the host internally. Finally, as the host plant approaches seed bearing, the mycelium produces spores within the seed organs which its branches have penetrated. These spores are scattered by the agencies before contemplated. The

[30] Loc. cit., p. 1592.

length of time during which the smut spores remain capable of germination is probably as long as seed is often kept. Spores of *Ustilago Carbo* have been germinated after preservation in the herbarium for $7\frac{1}{2}$ years.[31] Brefeld[32] observes that while barley dusty smut spores would not germinate after 1 year, those of oat smut still germinated readily after more than 6 years.

SPREAD OF SMUT IN FIELDS—EFFECT OF CHANGE OF LOCATION.

Some observed facts of spread of smut in fields are reserved for discussion at this time. As is stated of their results by Kellerman and Swingle,[33] artificial smutting, by dusting spores upon oats in blossom, did not give any decided results the second year, and would therefore not be expected to do so the first season. Four small plots of Seizure oats were chosen for dusting this season. One plot dusted with smut from 1894, gave 12.08 per cent.; one dusted upon same dates with spores of 1895 gave 8.84 per cent.; while the two not dusted and adjacent, showed 10.94 and 10.64 per cent. of smut, respectively. In each case about 2,500 stalks were counted. The result is, at this stage, of no importance. The dusting was repeated twice during blossoming.

But oats grown in proximity to smutted varieties certainly tends to become smutted. A table from Bulletin 57 of this Station[34] gives results for certain varieties 1891 to 1894, inclusive, and certain ones for 1894 only. The data there given are reproduced in Table III, to show results of 1895 in comparison:

---

[31] Zopf, Die Pilze, p. 218, quotes Liebenberg Unters. ü. d. Keimung d. Pilzsporen Pringh., Jahrb. II, p. 334. The source of the spores and whether from oats is not stated.

[32] Loc. cit., No. 221, p. 1593 note. Also Jour. Myc. VI, p. 155.

[33] Loc. cit., p 236.

[34] Hickman, J. Fremont. loc. cit., p. 114.

TABLE III—SMUT COUNTS IN OATS FOR SEVERAL YEARS.

Percentage of Smutted Panicles.

Variety.	Ohio Station.					Vermont Station.
	1891.	1892.	1893.	1894.	1895.	1895.
Black Prolific	3.2	2.8	13.3	34.0	31.0	29.4
American Banner	7.3	4.5	9.7	13.9	34.6	37.7
Race Horse	5.7	3.9	8.4	19.1	40.2	49.7
Lincoln	6.4	6.0	12.0	29.0	58.8	.....
Mammoth Russian	.....	.....	.....	5.9	19.5	.....
Wideawake	.....	.....	.....	2.6	16.9	.....
Welcome	.....	.....	.....	1.7	6.0	.....
White Wonder	.....	.....	.....	*	5.9	....
Seizure	.....	.....	.....	*	8.8	.....
Black Norway	.....	.....	.....	.....	45.2	31.2

* Less than 1%.

For the results of the Vermont Station we are indebted to Prof. L. R. Jones, Botanist of that Station.

The seed sown here and in Vermont was supplied by this Station, and taken from the same package after careful mixing of the whole contents. In the results for successive years the crop of the previous year was taken for sowing for the subsequent one.

Three varieties grown here among the badly smutted plots from seed the same as that supplied Mr. F. M. Selby, of Bartlett, gave the following results:

	Per cent. of smut at Station.	Per cent. of smut at Mr. Selby's.
Japan	2.49	0.97
White Swiss	5.59	0.57
Seizure	8.80	3.24

The counts are certainly very interesting. The difference in treatment was in soil and location, and in the application of fertilizers, which were sown with the oats on Mr. Selby's ground, with fertilizer drill. The

fertilized plots given in connection with Wideawake, p. 120, received the same treatment. The oats here were sown April 22, and those at Bartlett, April 4, for Japan and White Swiss, and April 12 for Seizure.

METHODS OF PREVENTION.

The successful methods of prevention for oat smut are now at least two in number, hot water at 130° to 135° F. by the method of Jensen,[35] and potassium sulphid (liver of sulphur) solution by the method of Kellerman and Swingle.[36] Either of these methods is thoroughly effective, and the matter of choice between them is likely to depend somewhat upon the taste or appliances of the user. The method of Jensen, a dipping process, requires more careful regulation and the use of an accurate thermometer, but has the advantages of cheapness, cleanness in manipulation, and diminished difficulty in drying the treated seed. The method of Kellerman and Swingle is a soaking process, of which the great advantage is that no thermometer is required, and, perhaps, less careful attention during treatment. But in either case there is an abundant return for special care and attention. The potassium sulphid, for the solution, must of necessity be weighed and directions followed for best results. The disadvantages of its use are the great difficulty in drying the treated seed, with corresponding trouble in sowing with the drill. Long soaking has, moreover, a disorganizing effect upon the seeds. The experiments, of which results are given, show the efficacy of both methods.

Aside from the methods of prevention now in use, there are others having a historical interest, and what is stated here concerning them is solely from this point of view. In the American Farmer of September 29, 1820, p. 215, a correspondent tells of oats so badly smutted that "the cradlers were nearly as black as colliers." This oats lay upon the ground for curing, in the old manner, and was turned after showers some four or five times, before binding and gathering. The same oats sowed the next season gave a crop free from smut (blast). This case shows the possible mechanical effect of washing. The process as one for practice would certainly prove expensive. In the Cultivator, May, 1856, p. 139, an Indiana correspondent, upon reporting much smut of oats in Southern Indiana, inquires the cause of oat smut and if there is a preventive known; also, whether the disease will continue to increase until it destroys the whole crop. The editor in comment states:

"Smut in oats is common in some countries, but we have never witnessed it as a serious evil. Like the smut of wheat, which is more generally known, it is a parasitic

[35] Loc cit., p. 413.

[36] Bul. 15 Kans. Exp. Sta., 1890, p. 129.

fungus growing in the grain, totally disorganizing it, and destroying its substance. Doubtless the same *preventive* remedy as is commonly used for the seed of wheat, would prove equally efficacious with oats, namely: Washing the grain thoroughly in water, or still better in brine (or giving the last washing in brine), and then rolling it well in dry, powdered, water-slaked, fresh lime, some hours before sowing. If the crop is now sown on clean, fresh land, the probability is that little smut will be seen in the future crop."

A quotation from the Cultivator in Farmer's Cabinet, 1837, vol. II, 107, states the method as "steeping the seed grain twelve hours in brine and rolling it in fresh slaked lime before sowing." We are to infer, I take it, that the method of brining and liming was prevalent between 1837 and 1856 where any preventive was applied.

Washing and then brining, combines both the mechanical and chemical procedures. Washing before treating is still recommended for the stinking smut of wheat, but is entirely unnecessary with oat smut. Copper sulphate (blue vitriol) solution has been used for oat smut by many experimenters. The results are generally less satisfactory, both as to prevention of smut and increase of yield, than the Jensen or the Kellerman-Swingle treatment.

Jensen published his success with hot water treatment for smut in 1887 and 1888. Kellerman and Swingle published the results of potassium sulphid treatment in 1890. In 1895, Jensen[37] appears as the advocate of a preparation for seed treatment. This preparation, called Ceres-powder (Ceres-pulver), is for sale by the disseminators, but has as yet been given no trial at this Station. Trial is contemplated next season. As will be seen from the title of the pamphlet, which lies before me, the "Ceres-pulver" is claimed to prevent the smuts of oats and barley and the root disease of mangold and sugar beets, and to increase the yield. The last claim immediately starts speculation as to the composition of this powder. Certainly there is no need to rely upon as yet unknown powders, whatever the name, when we have two such successful methods as those which follow, both of them increasing the yield.

METHODS OF TREATMENT RECOMMENDED.

The methods used for oats at this Station and recommended for prevention of smut and increase of yield are the Jensen hot water treatment and the Kellerman-Swingle potassium sulphid treatment. Attention has been confined to these because they seemed well established as to results, and the primary object of the whole investigation and of this

[37] Neue Methoden um den Brand in Hafer und Gerste und den Wurzelbrand in Zucker- und Runkel-Rüben zu beseitigen und die Ernte zu vermehren etc., Deutsche Ceres, J. L. Jensen & Co., Halle a. S., im Februar, 1895. Also in Zeitschrift für Pflanzenkrankheiten, V. Band, 1895, pp. 187-190.

publication, is to spread the use of well established methods of seed treatment among the grain growers of the State. The discussion and experiments have been limited to oat smut, but the hot water treatment appears to be applicable to the smuts of barley[38], if the grain is first soaked in water four hours and then allowed to stand four hours in wet sacks before treatment. It is then dipped, for five minutes only, in water at a temperature of 130° F.[39] The hot water method as herein described, is applicable to the treatment of wheat for stinking smut[40] without modification, except that 10 minutes is sufficient for immersion in hot water, at 133° F., and the grain should be previously immersed in cold water and skimmed. The principle is the same in all cases, namely: The destruction of adhering spores of smut without injuring the germinating power of the seed grain. (In case of barley there will be some injury to seed.) Moreover, the results of seed treatment have been found favorable to the germination of the treated seed, increasing its germinating power by hastening the development of the seedling. Seed treatment is apparently to be recommended even in cases where no smut occurs.

HOT WATER TREATMENT.

The hot water treatment given below, is essentially the same as given by the writers upon smut prevention; the details are those actually employed. This method consists in immersing the seed oats, previously raised in temperature, for 15 minutes in hot water at a temperature of 133° F. and then drying for sowing. The immersion destroys adhering smut spores without injury to the seed grain.

The vessels and apparatus required are:

1. A coarse, open gunny sack or wire mesh basket, of capacity of 1 to 2 bushels, with cover of same sort (12 meshes to the inch), to hold the grain during treatment. A perforated tin vessel is also excellent. It should not be more than one-half to two-thirds full of grain.

2. A well graduated thermometer, of Fahrenheit scale; the small floating dairy thermometer, for sale nearly everywhere at 25 cents, is the one used here; the large dairy thermometer is a good instrument. The small thermometer is not graduated above 160°, and will be ruined if thrust into boiling water for any length of time. There is little danger of breaking the thermometer, except through knocks or falls.

3. Two vessels of, preferably, 25 to 50 gallons capacity, to contain hot water, or in which the water is heated. In the first of these the

---

[38] *Ustilago hordei* (Pers.) Kell. and Swing., and *Ustilago nuda* (Jens.) Kell. and Swing.

[39] Swingle, W. T., loc. cit., p. 417.

[40] *Tilletia tritici* (Bjerk.) Winter, and *Tilletia fœtens* (B. & C.) Schroeter.

water is kept at 120° to 125° F.; it is for warming the grain preparatory to immersion in the second vessel. In the second vessel, which is for the actual seed treatment, the water is maintained at a temperature of 133° F. Where two kettles are used in which to heat the water, the grain may be dipped or immersed directly in them. Where a threshing boiler or steam from a boiler is used as a source of heat, deep tubs or 50 gallon barrels with one head removed, make satisfactory receptacles. In addition, a bucket of cold water and some ready source of hot water will be required.

4. The heating of the water may be accomplished by fires or by steam from boiler as above indicated. In the case of kettles, a small fire may be kept continuously under the second one.

5. A suitable floor or canvas upon which to dry the grain after treatment.

The two vessels, of ample capacity, should hold several times—8 to 10 times—the volume of seed grain to be immersed at any one time. Having these, they are filled with the hot water and the temperature is determined by the thermometer; the first, with water at 120° to 125° F., is for dipping the seed in order to warm it and to prevent too great fall of temperature in the second vessel; the second, with hot water at 133° F., is for the actual immersion of seed. The basket or sack containing the seed is dipped into the first vessel, with twirling; after a moment it is lifted and again dipped several times; when thoroughly warmed (less than a minute usually suffices for dipping into the first vessel) it is withdrawn and directly plunged into the second vessel, which has the water at 133° F. Here it is kept, with lifting and plunging many times (8 to 10), and with stirring the contents, by twirling, handling or otherwise, to secure thorough contact of all the grain with the hot water. This lifting and plunging and stirring of contents is very necessary to destroy all smut. The thermometer must be in constant use in this second vessel; if the temperature tends to fall, more hot water is added or steam is introduced. If the temperature rises too high above 133° F., cold water may be added. In all cases, after addition of hot or cold water, the water needs to be stirred to secure uniform heat, and in no case should very hot water be poured upon the grain being treated. The whole operation of immersion must be carefully conducted to insure success. At the end of 15 minutes the seed is withdrawn and, after draining, spread at once for drying. If not to be spread at once, the treated seed should be cooled with cold water immediately upon withdrawal. The treated grain is spread upon canvas or a clean floor free from smut spores, and dried with frequent stirring. It need not be completely dry before sowing, but if much moist.

great difficulty in drilling will result, especially in the matter of equal distribution of seed.

If large quantities of seed are to be treated, the amount treated at one time should not be too greatly increased, but appliances for lifting, handling and maintaining proper temperature may be readily devised. One of these suggested is a pole with hook to attach to treating vessel. This pole needs to be fixed at one end and should be capable of support at various heights at the other. The two barrels may be so situated as to be within the radius of the swing of the pole. A good suggestion in this line by Swingle, will be found in the U. S. Department of Agriculture's Year Book, 1894, p. 416.

PRECAUTIONS.

The needful precautions in the hot water method are:

1. Maintain the proper temperature of the water in the second vessel at 133° F., not permitting it to go above 135° nor to fall below 130° F. Too high a temperature will injure the grain, and too low will fail to destroy the smut.

2. See that the volume of scalding water is several times that of the seed treated at any one time.

3. Never fill the sack or basket containing the seed entirely full, as there must be room for movement of grain to secure uniform contact with the water.

4. Leave the seed in the second vessel 15 minutes.

POTASSIUM SULPHID TREATMENT.

This method relies upon the chemical effect of potassium sulphid as a fungicide, and is based upon spore destruction without grain injury, as is the other. The potassium sulphid (liver of sulphur) may be obtained in fused cakes at nearly all drug stores, the price varying from 25 to 40 cents per pound, according to quantity purchased. It should be kept tightly closed in a bottle. This salt is very readily soluble in water and makes a strongly alkaline, soapy solution, of yellowish or brown color.

NOTE. Seed treatment by seedsmen or large dealers is worthy careful calculation. One who treats thoroughly the seed oats or other grain offered for sale, ought to have no difficulty in realizing a good return upon the investment. The treatment may be made some weeks before the seed is wanted and if thoroughly dried no impairment of vitality will take place. The hot water method is the only one applicable on a large scale, without excessive care in drying the seed. For such a purpose, two large hogsheads, in which the water is heated from a steam pipe, will prove very satisfactory. The immersing vessel may be made of larger capacity, holding several bushels, and consisting of metal framework, covered with wire netting, 12 meshes to the inch; the lid to be of the same material. If this vessel is handled by means of a pole, as suggested by Swingle, the work will not be over heavy and treatment may proceed rapidly. In this way the cost of treatment may be reduced to a few cents per bushel, and an added price of 15 cents per bushel might be realized.

The materials and apparatus needed in this method are weighed quantities ($\frac{3}{4}$ or $1\frac{1}{2}$ lbs.) of potassium sulphid, a suitable wooden vessel, as a barrel or a large tub, and a convenient drying place. Reserve quantities of cold water are also required.

Make a $\frac{3}{4}$ per cent. solution, by dissolving $1\frac{1}{2}$ pounds of the fused potassium sulphid in 25 gallons of water contained in the wooden vessel. Stir the solution thoroughly; about three bushels of oats, if loose, or a smaller quantity in sack, may be treated at once. The solution should stand a few inches above the oats to be treated, so that the grain is completely covered. Stir the whole well to secure wetting of all the grain. The oats are left in the solution 24 hours (in the seed we treated, $\frac{1}{2}$ per cent solution, 18 hours, but better longer). Stir a few times during this period. The liquid may be poured off at the end of the time, and the grain should be washed with fresh water to facilitate subsequent drying. The solution can be used once or twice more, but should not be used oftener.

The precautions in the potassium sulphid treatment are:

1. Have enough liquid to cover grain several inches deep, as great swelling of the grain occurs.

2. Stir the solution well before adding the seed and also during the soaking.

3. Do not put the solution into a metal vessel, nor use the same solution more than two or three times.

4. Wash with water after treatment.

The great difficulty is in drying the seed, which is likely to be more or less sprouted and very much swollen. The Kansas recommendation is to sow before drying thoroughly, yet fairly good drying is necessary to successful seeding. Washing after soaking is a great aid in drying.

THE EXPERIMENTS OF 1895.

These experiments, with Jensen and Kellerman-Swingle methods of seed treatment, were conducted upon several varieties of oats, chiefly those with very high percentages of smut. In this respect factors were introduced into the experiment that, so far as I have observed, are not common to previous experiments in this line. Difficulties are also met which make any very sweeping statements impossible. It is the aim in the presentation here made to let the experiments speak for themselves.

The plots, 21 in all, including one which was not harvested separately, were of $\frac{1}{30}$ acre area, lying contiguously, except for a break between plots 16 and 17 as shown in the diagram of plots. This break was to escape a local variation in soil. The soil of the plots is a fairly uniform, light loam, of low fertility. The field was in ensilage corn in 1894

Diagram of Oats Plots as Treated for Smut, 1895.

"A."	Race Horse, untreated. 41.62 per cent. smutted.
1.	Race Horse; hot water, 132.8° F., 15 minutes. 0.24 per cent. smutted.
2.	Race Horse, untreated. 39.47 per cent. smutted.
3.	Race Horse; potassium sulphid, ½ % solution, 18 hours. 1.006 per cent. smutted.
4.	Black Prolific; hot water, 132.8° F., 15 minutes. 0.21 per cent. smutted.
5.	Black Prolific, untreated. 31.05 per cent. smutted.
6.	Black Prolific; potassium sulphid, ½ % solutson, 18 hours. 0 21 per cent. smutted.
7.	Lincoln, untreated. 58.82 per cent. smutted.
8.	Lincoln; hot water, 132.8° F., 15 minutes. 2.21 per cent. smutted.
9.	American Banner, untreated. 34.56 per cent. smutted.
10.	American Banner; hot water, 132.8° F., 15 minutes. 2 per cent. smutted.
11.	Mammoth Russian, untreated. 19.49 per cent. smutted.
12.	Mammoth Russian; hot water, 132.8° F., 15 minutes. 0 51 per cent. smutted.
13.	New Red Rust Proof, untreated. 18.41 per cent. smutted.
14.	New Red Rust Proof; hot water, 132.8° F., 15 minutes. 0.24 per cent. smutted.
15.	Black Norway, untreated. 45.21 per cent. smutted.
16.	Black Norway; hot water, 132.8° F., 15 minutes. 1.03 per cent. smutted.

17.	Seizure, untreated. 7.29 per cent smutted.
18.	Seizure; hot water, 132.8° F., 15 minutes. 0.45 per cent. smutted.
19.	Seizure, untreated. 10 40 per cent. smutted.
20.	Seizure; potassium sulphid, ½ % solution, 18 hours. 0.11 per cent. smutted.

and had been manured with stable manure the previous winter. No fertilizer was applied in 1895. The drainage of the soil is good, sloping very slightly to the north, and soil conditions were fairly good, the earth having been moist and mellow at the time of seeding. For the preparation of the soil, sowing and harvesting this department is under obligations to the Agricultural department of this Station. The seed, treated two days previously, was well dried and sown with drill at the rate of seven pecks per acre, April 22, 1895. As before stated, the seed was in many cases from plots having a high percentage of smut in 1894, and in all cases except two, the per cent. of smut had been determined in that season. There were imperfections of seed treatment, such as filling sacks too full, using too low vessels to contain the hot water, and consequent difficulties in stirring the grain well during treatment.

The following were the percentages of smut in 1894, in the plots from which seed was obtained and the per cent. of smut in untreated plots in 1895:

	1894.	1895.
Race Horse	19.1 per cent.	40.16 per cent.
Black Prolific	34 0 "	31.05 "
Lincoln	29.0 "	58.82 "
American Banner	Not known.	34.56 "
Mammoth Russian (cluster)	5.9 per cent.	19.49 "
New Red Rust Proof	Not known, high.	18.41 "
Black Norway	" "	45.21 "
Seizure	Less than 1%.	8.80 "

This shows a large amount of smut to deal with and the results indicate varietial differences or other undetermined factors. The table gives variety of oats, treatment of seed, smut results, yield of straw, yield of grain, and effect of treatment on yield, both in respect to increase per acre and to the replacement of smutted panicles.

The counting was done, in nearly all cases, by measuring off at a fixed point, 10 feet on each of 8 rows, and counting total stalks and number of smutted panicles. In addition to this area, two others were measured off, 4 feet on each of 8 rows and the counts similarly made. The four-foot areas were selected to represent average conditions. The table shows total areas counted in each case.

TABLE IV.—Results of Treatment of Oats for Smut.

Plot.	Variety.	Treatment of seed.	Smut results.				Yield of straw.		Yield of grain.		Effect of treatment (per acre).			Plot.
			Total heads counted.	Area counted.	Number heads smutted.	Per cent. smutted heads.	Weight per plot.	Weight per acre.	Yield per plot.	Yield per acre.	Increase over untreated.	Calculated amount to replace smutted heads.	Net increase aside from smut prevention.	
							Pounds.	*Pounds.*	*Pounds.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	
"A"	Race Horse	Untreated	1,307	5′ 4″x8′	544	41.62	*							"A"
1	"	Hot water	2,465	5′ 4″x18′	6	0.24	54 25	1,627	60.75	56.95	25.07	0.14	3.47	1
2	"	Untreated	2,714	5′ 4″x18′	1,083	39.47	61.00	1,830	34.00	31 88		21.74		2
3	"	Potas.sulphid	2,482	5′ 4″x18′	25	1.01	40 75	1,222	59.25	55.55	23 67	0.57	2 50	3
4	Black Prolific	Hot water	2,863	5′ 4″x18′	6	0.21	45.00	1,350	67.00	62.81	18 75	0.12	—0.97	4
5	"	Untreated	2,557	5′ 4″x18′	794	31.05	86.00	2,580	47 00	44.06		19 84		5
6	"	Potas.sulphid	2,314	5′ 4″x18′	5	0.21	69 00	2,070	76.00	71 25	27.19	0.15	7.50	6
7	Lincoln	Untreated	3,033	5′ 4″x17½′	1,784	58 82	69.50	2,085	30.50	28 60		40 85		7
8	"	Hot water	2,619	5′ 4″x18′	58	2.21	51.75	1,552	73.25	68 67	40.07	1 55	0.77	8
9	American Banner	Untreated	2,633	5′ 4″x18′	910	34.55	79.50	2,385	45.50	42.66		22.53		9
10	" "	Hot water	2,792	5′ 4″x18′	56	2.00	58.50	1,755	71 50	67.03	24.37	1.37	3.21	10
11	Mammoth Russian	Untreated	2,315	5′ 4″x18′	457	19.49	65 00	1,950	50.00	46.88		11.35		11
12	" "	Hot water	2,131	5′ 4″x18′	11	0.51	51.50	1,545	68.50	64.22	17.34	0.33	6.32	12
13	New Red Rust Proof	Untreated	1,434	5′ 4″x8′	264	18.41	47 50	1,425	47.50	44.53		10.05		13
14	" "	Hot water	2,994	5′ 4″x18′	7	0.24	43.75	1,312	56.25	52.73	8.20	0.13	—1.72	14
15	Black Norway	Untreated	1,935	5′ 4″x18′	902	45.21	49 50	1,485	35.50	33 28		27.46		15
16	"	Hot water	2,228	5′ 4″x18′	23	1.03	57.00	1,710	63.00	59.06	25 78	0.51	—1.17	16
17	Seizure	Untreated	1,934	5′ 4″x18′	141	7.29	48 00	1,440	57.00	53.44		5.28		17
18	"	Hot water	1,748	5′ 4″x18′	8	0.45	69.50	2,085	65.50	61.41	7.03	0.15	3.07	18
19	"	Untreated	1,836	5′ 4″x18′	191	10 40	56.00	1,680	59.00	55.31		5 28		19
20	"	Potas.sulphid	1,800	5′ 4″x18′	2	0.11	57.00	1,710	68.00	63.75	9.37	0.15	3.07	20

* Not gathered separately.

TABLE V.—SUMMARY OF TABLE IV.

Plot	Treatment of seed.	Per cent. of smut.	Yield per acre.	Increase over untreated plots.	Net increase or decrease—aside from smut prevention.
			Bushels.	*Bus. per acre.*	*Bus. per acre.*
1	Hot water	0.24	56.95	25.07	3.47
2	Untreated	39.47	31.88		
3	Potas. sulphid	1.01	55.55	23.67	2.50
4	Hot water	0.21	62.81	18.75	—0.97
5	Untreated	31.05	44.06		
6	Potas. sulphid	0.21	71.25	27.19	7.50
7	Untreated	58.82	28.60		
8	Hot water	2.21	68.67	40.07	0.77
9	Untreated	34.56	42.66		
10	Hot water	2.00	67.03	24.37	3.21
11	Untreated	19.49	46.88		
12	Hot water	0.51	64.22	17.34	6.32
13	Untreated	18.41	44.53		
14	Hot water	0.24	52.73	8.20	—1.72
15	Untreated	45.21	33.28		
16	Hot water	1.03	59.06	25.78	—1.17
17	Untreated	7.29	53.44		
18	Hot water	0.45	61.41	*7.03	+3.07
19	Untreated	10.40	55.31		
20	Potas. sulphid	0.11	63.75	*9.37	†3.07

* Average, 8.20. † Average. Net increase, 2.37 bushels.

If this series of experiments gave results quite at variance with those previously obtained elsewhere, we could scarcely claim that much is shown by them. But yielding, as they do, confirmation of previous results with oats containing like percentages of smut, they add their modicum to the proof upon this subject. The variation in amount of smut in the different treated plots may be attributed, I believe, to the imperfect

stirring of the seed during treatment. The necessity of this agitation should be emphasized. Sacks were used for immersing the seed, and for the reason that gunny sacks are more readily secured than wire mesh or other baskets.

From the foregoing summary of results it is observed, that treated plots of Race Horse, Black Prolific, Mammoth Cluster, Seizure and American Banner gave a net increase, beyond smut prevented, amounting to 3 bushels or more per acre. Two varieties failed to give a net increase beyond smut prevented, although giving increased yields of 8.2 to 25.8 bushels per acre over the untreated plots. The average of all is a net increase of 2 37 bushels per acre.

Upon the plots of seizure, 17 to 20 inclusive, wherein the amount of smut in untreated plots was 8.85 per cent., a proportion much nearer the average in the State, we can, I believe, base some conclusions of value. These treated plots give an *average increase in yield of* 8.2 *bushels per acre and a net increase of* 3.07 *bushels per acre over the average of the two adjacent untreated plots.* **In other words, this and the average of all as well, indicates a net increase in yield per acre which more than covers the cost of seed treatment; the amount of increase** (*in this case* 5.28 *bushels per acre*) **due to smut prevention being the net profit.** Applied to the estimated loss of $480,000 in the whole State, these results show a large saving. Further comment seems wholly unnecessary.

SUMMARY.

1. Smut in oats, a disease long known and generally regarded as unimportant, really causes large losses among growers.

2. The amount of smut varies. This was about 20 per cent. of the whole at the Station in 1895, and 6 per cent. appears to be a conservative estimate of the smut in the State.

3. The losses caused by smut therefore amount to $480,000 annually in Ohio, and more than $18,000,000 per year for the United States.

4. Oat smut is due to a parasitic fungus, *Ustilago Avenæ*, or its variety *levis*, whose spores adhere to the seed grain and germinate with the seed; the mycelium enters within the seedling, finally reaches the grain bearing parts and destroys them.

5. The smut is prevented by the destruction of all these attached spores, which is possible by seed treatment, without injury to the grain.

6. **Immersing the seed oats for 15 minutes in hot water at a temperature of 133° F. not only destroys the smut but increases the yield beyond mere smut prevention.**

7. **Soaking the seed for 24 hours in a $\frac{3}{4}$ per cent. solution of potassium sulphid, made by dissolving $1\frac{1}{2}$ pounds of the salt in 25 gallons of water, is equally efficient in smut prevention.**

8. **The net increase in yield beyond smut prevention appears sufficient to defray cost of seed treatment.**

EXPLANATION OF PLATE.

Plate 1. Loose Smut of Oats, *Ustilago Avenæ* (Pers.).

Fig. 1. Head or panicle of oats, with all but the uppermost grains smutted.

Figs. 2 and 3. Small panicles, with all the grains smutted. All natural size. Cut obtained from Kansas Experiment Station.

PLATE I.

SMUT OF OATS.